Figure 3-5: View to the west from Tanager Drive, looking toward Glass Road. These power lines are connected to Glass Road lines, but are not equipped with BPL communications hardware boxes. These lines are just west of the Spencer residence.

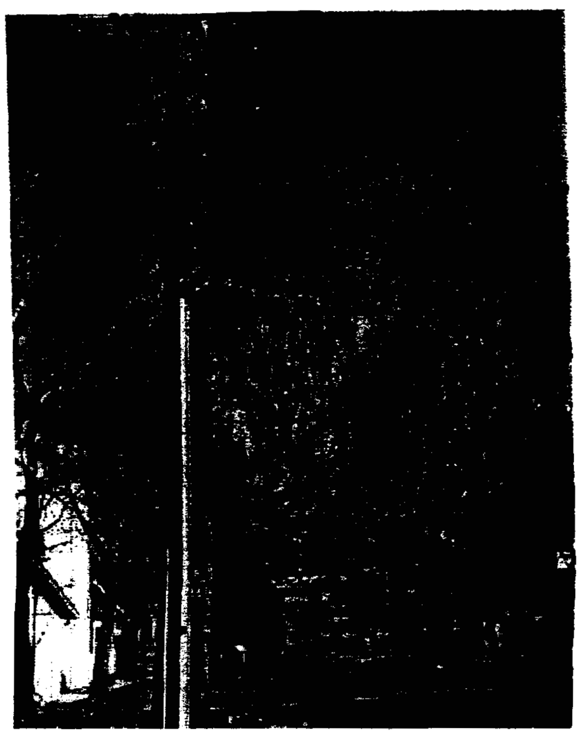


Figure 3-6: View to the east from Glass Road looking toward Tanager Drive. This is the connection point for the above circuit.

Figure 3-7 shows the antenna support tower and some of the antennas used in the operation of station WØSR. This view is toward the front of the house.

Figure 3-7: View from Tanager Drive of WØSR antenna tower

The antennas and related hardware in use at WØSR are as follows:

- Tower: Commercial self-supporting steel type, 48 feet overall height
- Antenna mounting: Side arms on tower for wire antennas; rotating mast for the Tri-Band Beam and WARC Dipole.
- 160 m Antenna (1.8 to 2.0 MHz): Inverted-L (wire) supported by the tower at 46 feet, coax is RG-58, 32 feet long. This antenna runs from the tower at a compass bearing of approximately 240 degrees.
- 80m/40m Inverted-Vee (3.5 to 4.0 MHz and 7.0 to 7.3 MHz): Two dipoles (wires cut to resonate at about 3.8 and 7.15 MHz, respectively) supported at their apex by the tower at 47 feet, fed from a single RG-213 coax, 75 feet long. The 80m antenna runs at a compass bearing of approximately 20/200 degrees, and the 40m runs at 110/290 degrees.
- Tri-Band Beam[3]: Hy-Gain™ TH7-DXX (Yagi-type) at 49 feet fed with RG-213 coax, 75 feet long. This antenna is rotatable.
- WARC Dipole[4]: Cushcraft™ D3W rotatable dipole at 54 feet fed with RG-213 coax, 80 feet long. The antenna is a single element dipole which

[3] "Tri-Band Beam" refers to a common antenna configuration which provides operation on three (3) of the Amateur Radio Service HF bands: 20m (14.0 to 14.35 MHz), 15m (21.0 to 21.45 MHz), and 10m (28.0 to 29.7 MHz). The antenna design is such that it uses multiple elements on each band so as to provide forward power gain over a single element dipole antenna.

[4] "WARC Dipole" refers to a common antenna configuration designed to provide operation on the three (3) bands allocated to the Amateur Radio Service during the World Administrative Radio Conference ("WARC") of 1979. These bands are at 30m (10.1 to 10.15 MHz), 17m (18.068 to 18.168 MHz), and 12 m (24.89 to 24.99 MHz).

employs traps as tuned elements for each of the bands. It is mounted above the Tri-Band Beam on the tower mast and is orthogonal to the orientation of the Tri-Band Beam.

- 80/40 Vertical (3.5 to 4.0 MHz and 7.0 to 7.3 MHz) : Butternut™ HF-2V, ground mounted, fed with 45 feet RG-213 coax, and fitted with approximately 60 radials buried just below the surface of the ground.

The coaxial cables from all five antennas are routed to an Ameritron model RCS-8V remote switch, which is located inside the house, near where the cables enter. A single RG-213 coaxial cable, having a length of 25 feet, runs from the switch to the operating position, and has a worst case loss of about 0.3 dB at 30 MHz, the highest operating frequency for which it is used. The purpose of the switch is to allow rapid selection of antenna type from the operating position without having a large number of rather bulky cables routed all the way to the operating position. Switch manufacturer Ameritron rates loss of their device as "less than 1 dB at 150 MHz"[5]. Since loss is a linear function relative to frequency, the worst case expected loss through the switch at 30 MHz would be approximately 0.2 dB.

The *ARRL Handbook*, a well-respected engineering design guide, has published typical performance specifications for most coaxial cables in typical Amateur Radio use for many years. (Coaxial cable is a type of signal transmission line commonly used to interconnect antennas and associated radio equipment.) The tables for the cable types used in this radio station installation give attenuation (loss) values as follows[6]:

- Type RG-58/U: approximately 0.47 dB loss per 100 feet at 2 MHz (used only for the 160m Inverted-L antenna)
- Type RG-213/U: approximately 1.3 dB loss per 100 feet at 30 MHz (just above the 10m Amateur band) and approximately 0.56 dB loss per 100 feet at 7 MHz (low end of the 40m Amateur band)

Since only 32 feet of type RG-58/U is used between the Ameritron switch and the 160m Inverted-L, cable loss in the region of 1.8 to 2 MHz is on the order of 0.16 dB, a negligible value. The 25 feet of RG-213/U between the RCS-8V switch and the station adds perhaps another 0.1 dB. The total losses in this frequency range are negligible.

The 80/40m inverted-V antenna will have a worst case total line loss (including the switch) of about 0.6 to 0.7 dB at 7.3 MHz, the top end of the 40m band.

The 80/40 vertical will have a worst case line loss of about 0.5 dB at 7.3 MHz with its shorter total feed line run.

---

[5] Ameritron web site, Model RCS-8V, viewed on May 24, 2004.
[6] *The 2002 ARRL Handbook for the Radio Amateur*, American Radio Relay League, Newington, CT, pg. 19.6.

The Tri-Band beam and WARC dipole, each of which have total feed line length at or near 100 feet, will have approximately 1.5 dB of cable loss at their respective highest frequency (the region of 29.7 and 24.9 MHz, respectively) bands of operation.

While measurable, the losses discussed above are not significantly high. With total system measurement uncertainty being on the order of ± 2 dB[7], and since all signals intercepted by the antennas at any given frequency will be attenuated equally, the relationship between all antenna-coupled signals and atmospheric or man-made noise is not affected by these levels of transmission losses. Since the goal of this BPLSC testing was to make measurements at the actual operating position of the station, antenna factors and cable losses are relative only and do not factor into any measurement correlation. All cables and antennas used for data collection were the same for all tests.

The following figures show the actual antennas as they exist and as used for measurement purposes:

Figure 3-8: General view of antennas: (top to bottom) WARC band dipole; TH7-DXX Tri-Bander; side arm support for Inverted-V; top of ground-mounted vertical is in foreground.

[7] Measurement uncertainty for the equipment used in this testing is described in the Test Approach section of this paper.

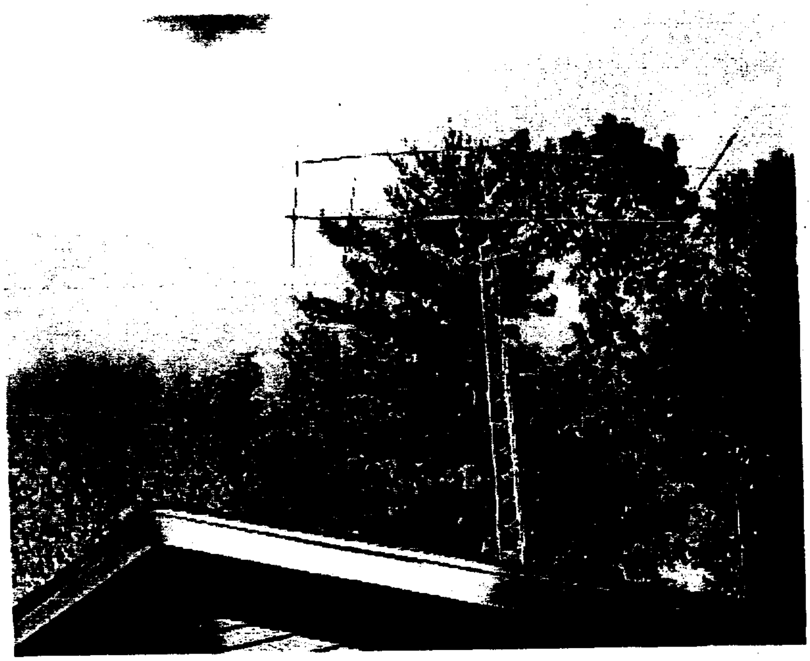


Figure 3-9: The 160m Inverted-L antenna is a horizontal wire visible to the left of the tower, above the roof peak.

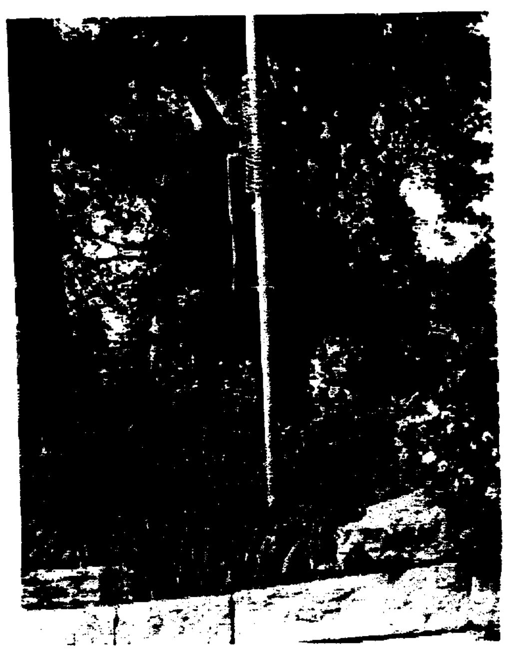


Figure 3-10: Base of Vertical

Figure 3-11: Sidearm mount for 80-40 meter Inverted-V

Figure 3-12: Tri-Band Beam and WARC Dipole, and one side of the 40m Inverted-V

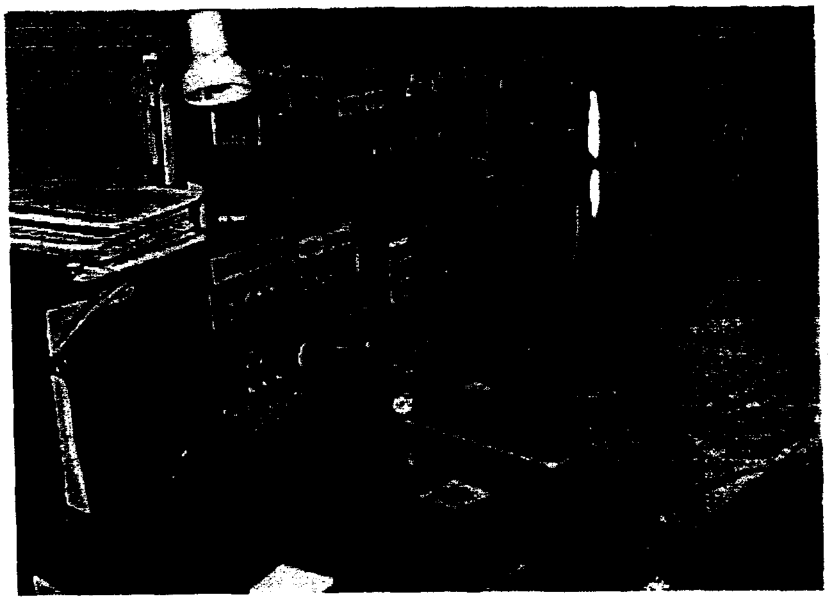


Fig 3-13: Mr. James Spencer at the operating position of Amateur Radio Station WØSR.

Fig. 3-14: Mr. Dale Svetanoff takes notes as Mr. Spencer looks on. The Agilent E4411B spectrum analyzer is sitting atop the Wandel & Goltermann SPM-17 Level Meter. Either instrument may be connected to the regular radio station coaxial cable as required. (The coaxial cable is the black cable shown connected to the input connector of the Agilent E4411B in the above photo.)

4. TEST APPROACH

The Cedar Rapids BPL Steering Committee asked Mr. Dale Svetanoff, WA9ENA, to perform the on-site testing at Mr. Spencer's station location. A spectrum analyzer was set up in the WØSR radio operations room of Mr. Spencer on three (3) different dates: April 8th, May 10th, and May 19th, all in 2004. The spectrum analyzers used were Agilent Technologies Model E4411B, serial numbers MY41441567 (calibration due 09/30/2004) and MY41441574 (calibration due 09/30/2004). Analyzer serial number MY41441567 was used on April 8th and May 10th, while analyzer serial number MY41441574 was used on May 19th.

Both spectrum analyzers have the following main characteristics[8]:

Table 4-1: Spectrum Analyzer Characteristics

Characteristic	**Specification**
Frequency range	9 kHz to 1.5 GHz
Amplitude accuracy	As noted below:
At reference setting[9]	± 0.4 dB
Overall amplitude accuracy, 20 to 30 ºC	± (0.6 dB + absolute frequency response)
Input attenuator uncertainty at 50 MHz	10 dB is reference; 20 to 60 dB attenuation is ± (0.1 dB + .01 x attenuator setting)
Frequency Response ➢ 10 dB attenuation, 20 to 30 ºC ➢ 0, 5, 15 to 60 dB attenuation	 ± 0.5 dB ± 1.0 dB, characteristic

Both spectrum analyzers were previously calibrated with standards traceable to the National Institute of Standards and Technology, and calibration certificates are on file.

Neither spectrum analyzer was used at the reference setting[9]; thus, the average measurement uncertainty for amplitude error factors is the sum of the worst case attenuation setting and its uncertainty with respect to frequency response. This would be a value ranging from ± 1.6 dB (the 10dB attenuator was used for some

[8] *Agilent ESA-L series Spectrum Analyzers Specifications Guide*, Agilent Technologies, Part number E4403-90032, August, 2002, pp. 78-79.

[9] Settings are: reference level -25 dBm; input attenuation 10 dB, center frequency 50 MHz; Res BW 1 kHz, Video filter 1 kHz; amplitude scale linear or log; span 2 kHz; sweep time coupled; signal at reference level.

measurements) to as much as ± 2.0 dB, using the above information and 30 dB of attenuation. Tests were conducted with the equipment being in a temperature environment of 20 to 30 ºC. Test data was recorded onto floppy discs via a built-in floppy drive on each analyzer. The data was saved as a *.csv* file which was later converted to an Excel spreadsheet. All spreadsheets contain the serial number identification of the spectrum analyzer used and relevant scan parameters. All plots were run using Excel.

Other equipment used during the tests, but not for purposes of recording data:

- Wandel & Goltermann Model SPM-17 Level Meter, range 10 kHz to 110 MHz - used to audibly monitor the various BPL carrier signals and obtain sound files of those signals
- Icom IC-765 Transceiver, 1.8 MHz through 30 MHz (owned by Mr. Spencer) – Used to obtain sound files of BPL signals and for comparison of signal strength at time of test relative to other times (using the relative reading "S" meter). This is the primary radio at station WØSR.
- Sony Hi8 Video Camera – used to record video with sound during various tests
- Nikon Coolpix® 775 Digital Camera – used to record still photographs of the equipment installations (BPL and at Amateur station WØSR), the surrounding neighborhood environment, and brief digital movies of spectrum analyzer sequences showing BPL signal activity.

The purpose of the additional equipment listed was to substantiate and confirm the presence (or absence) of BPL and other interfering signals when collecting the test data. Since BPL signals are, by nature, changing at various intervals, capturing the changes and the related effects upon a communication system is difficult when recording plots at specific points in time. The BPL signal changes manifest themselves both audibly and visually, and the video camera was used to capture samples of activity. Unfortunately, the actual captured video and sounds can not be included in this report. It is anticipated that portions of the audio and video clips, as well as numerous digital images, will be available from the Cedar Rapids BPL Steering Committee as a support exhibit to this test report.

Mr. Spencer has multiple computers and a Local Area Network ("LAN") within his home. All computers and the LAN were shut down during all tests to ensure that they did not contribute to the measured signal levels. All of the radio equipment in the radio operations room was turned off, with the exception of the control box for the Ameritron RCS-8V remote switch. This control box contains only a rotary switch, a few resistors, and LED indicators. There are no digital circuits, and power is provided by the manufacturer's linear (non-switching) wall type power supply. Power must be applied continuously to the relay that switches the selected antenna onto the shack feed line. The rotator control box was used to orient the Tri-Band Beam and WARC Dipole for maximum signal indication. This controller is in the "Off" state until and unless it is commanded to rotate the antenna mast.

No data was taken during antenna rotation; maximum signal was visually determined from either the spectrum analyzer display or S-meter reading of the IC-765 station transceiver.

One of the key issues in recording the data was consideration in selection of the spectrum analyzer filter bandwidth(s) to be used. Most of the test data was collected using a resolution bandwidth of 3 kHz, with the follow-on video filter bandwidth set to either the same, or greater, bandwidth. (The video filter in a spectrum analyzer has the effect of smoothing the trace by reduction of noise and, when a narrow bandwidth has been selected, lowers the noise floor of the spectrum analyzer receiver.) The selection of 3 kHz was driven by the fact that typical communications receivers use intermediate frequency ("IF") filter bandwidths in the range of approximately 2.1 kHz to 2.8 kHz for single sideband ("SSB") operation; since the use of regular, typical, Amateur Radio antennas to make these measurements was *the* point in this work, it was felt that the spectrum analyzer should replicate the characteristics of the station receiver as well. Communications using Morse code continuous wave ("CW") and certain digital modes can, and do, use narrower bandwidths. The result of using filters that are closely matched to the bandwidth of the transmitted signal is to reduce the extraneous noise presented to the radio operator (or decoding system, in the case of digital signals), resulting in an optimized signal to noise ratio for the given mode.

Some data was taken using spectrum analyzer bandwidths less than 3 kHz. This action resulted in better visibility of the typical BPL waveform, which has Orthogonal Frequency Domain Multiplexing ("OFDM") modulated carriers at about 1.1 kHz intervals across the spectrum of operation. An IF filter having 3 kHz bandwidth tends to integrate 3 such carriers into a single waveform profile, making it difficult to ascertain by visual inspection of plots that BPL signals are indeed being viewed. The differences in the filter action can be readily seen in some of the data plots in Appendix 1.

The test plan decided upon was as follows:

- For the April 8th tests, made about one week after trial BPL operations began near Mr. Spencer's station, spectrum analyzer scans were made using all five (5) of the available antennas. Each antenna was used in ranges near and within its rated operating frequency range. The total spectrum surveyed was 1 MHz through 33 MHz. BPL was operational during all of these scans.
- The plan for May 10th had been to obtain baseline scans, identical in frequency span to those taken on April 8th, so that a comparison could be made between BPL on and BPL off conditions. Alliant Energy had agreed to switch off the BPL signals for two hours at Mr. Spencer's request. Several minutes after Mr. Spencer contacted Alliant, a decrease in the BPL spectrum was noticed, but not a complete elimination of the signals[10].

[10] It was subsequently learned that Alliant Energy had, indeed, commanded the BPL units to terminate operations. However, the units operate in "daisy chain" fashion: the operational commands are sent to the

No data plots were taken, but video recordings with sound were made prior to the requested shutdown. Interference was still present even with the reduced spectrum of signals. Visual comparisons were made between plotted graphs of the April 8th scans and the signals present before shutdown in an effort to confirm that signal conditions on this day were similar to those experienced on the earlier date.

- Alliant Energy agreed to a second attempt at shutting down the trial system for two hours. This attempt was successful on May 19th. A few test scans were run with the spectrum analyzer prior to shutdown to confirm similarity to the April 8th signal conditions. Once shutdown was confirmed, scans were made to plot the ambient noise conditions on all of the Amateur bands between 1 and 33 MHz. (It should be noted that Mr. Spencer had filed several previous complaints with Alliant Energy regarding excessive power line noise at his location. That noise was still present, having been made less evident by the BPL signals for the previous several weeks.) New scans were run using averaging techniques to mitigate some of the effects of the power line noise upon the baseline. When BPL signals re-appeared two hours after shutdown, it was noticed that they did not have the same spectral distribution as prior to shutdown. Detailed, limited range scans were run on the 17m and 15m Amateur bands, as these were the areas of greatest signal strength after the system returned to operation.

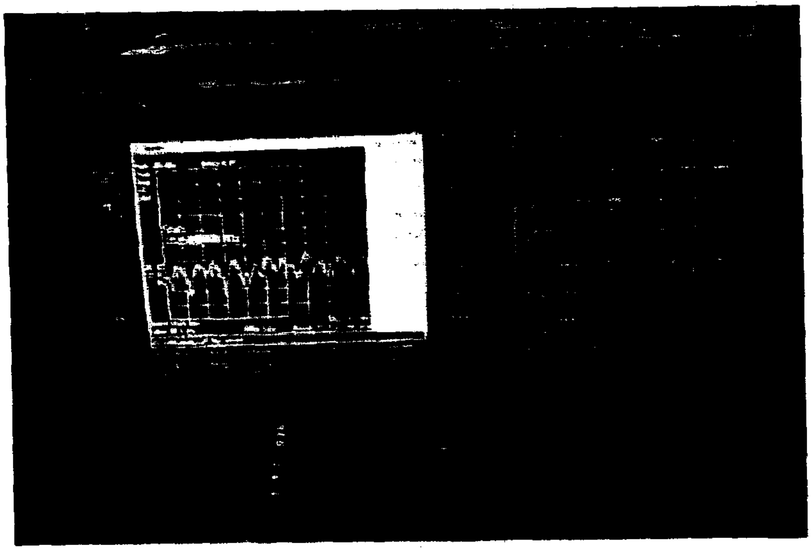


Fig. 4-1

Agilent E4411B Spectrum Analyzer with spectrum plot showing BPL signals between 18.05 and 18.10 MHz. The floppy disc drive for recording data is visible at the right edge of the photo.

---

unit nearest the power substation on Glass Road. That unit sends commands downstream to the other units via the power line system. In this case, it appeared that the first and second units switched off, but not the third and fourth units. It is believed that this effect may have been due to reduced injection levels within the BPL units, as told to Mr. Spencer by Alliant Energy representatives.

5. TEST DESCRIPTION

The Tri-Band Beam and WARC Dipole antennas can be rotated in azimuth a full 360 degrees. For purposes of these tests, these antennas were rotated to a position which maximized interfering signals. The heading which produced that condition was westward, toward the distribution power lines upon which the BPL circuit is implemented.

Data was taken at multiple frequency ranges between 1.0 MHz and 33 MHz. Each frequency range was chosen to match with the associated antenna operating range. The BPL signal was impulsive (varying amplitude), with the carriers distinctive and audibly distinguishable from 60 Hz power line noise with any of the receivers. The individual carriers could be shown by careful selection of spectrum analyzer IF bandwidth, and could be heard with either the W&G SPM-17 or the Icom IC-765. However, the required spectrum analyzer bandwidth for "imaging" carriers was narrower than the bandwidth used for routine voice communications.

Tests on April 8th and May 10th were run at about the same time of day: starting at approximately 4:30 pm CDT and ending at approximately 6:00 pm CDT. The tests on May 19th began at about 4:30 pm, and shut down of the BPL signal occurred at 4:50 pm for a period of two (2) hours. Test data was taken with BPL off until approximately 6:15 pm, and more data was taken when BPL returned because it appeared that the spectral characteristics of the system were different after it reactivated.

The BPL Steering Committee is grateful to Alliant Energy for their cooperation as indicated by their willingness to temporarily turn off the BPL system for our tests.

6. CONCLUSIONS

The presence of, or lack of, BPL signals is readily detectable on any of the sweep plots which have signal/no signal plots. BPL signals are readily apparent over the levels of natural noise, which increase at lower frequencies. This is borne out by review of any of the sweep plots which cover a large portion of the HF spectrum.

A reference line to show where a 1 microvolt signal (in a 50 ohm system) lies has been added at -107 dBm. This is representative of the sensitivity exhibited by typical narrow band communications equipment, such as Mr. Spencer's receiver, as well as those on the general market, past and present (see Table A2-1in Appendix 2). <u>It can readily be seen that, for the most part, BPL signals intercepted by the antennas at station WØSR are well above the sensitivity levels of these receivers.</u>

The notching of BPL to minimize interference to Amateur Radio communications is evident in some plots, but even at the given separation distance from the active BPL lines and associated hardware, these levels are still too high to avoid harmful interference. In some cases, it was noted that the notches had not been located in proper relation to the Amateur Radio band.

The photographs of the spectrum analyzer traces (Part B of Appendix 1) do show the transitory nature of the OFDM carrier signals, which result in changing audio tones when heard with an SSB receiver. Reception of desired signals through these audio tones, when they are nearly as strong, or stronger, than the desired signals is not possible. Practical receiver filtering and audio processing are not able to adequately distinguish between desired signals and these injected tones. Further, an additional BPL signal reduction of 20 dB would be needed just to maintain the present high signal levels if Mr. Spencer's station were located at one-tenth its present distance from the BPL signal source.

An inspection of the installed trial BPL system shows that the vendor and Alliant Energy have made a very poor choice in signal transmission: the BPL tones are being sent using but one wire from station to station. The effect, contrary to non-factual comments filed with the FCC by some vendors, is to create antennas that will radiate along their length. Depending upon frequency and length of the actual power line segment, a "long wire effect" may, in fact, produce some degree of directional signal gain, resulting in enhanced interfering emissions (at some frequencies) from the ends of each unbalanced segment[11].

The BPL Steering Committee concludes that BPL systems of the type tested are not practical in the MF and HF regions, especially where they are co-located in near proximity to licensed users of the spectrum.

7. TEST PERSONNEL

The test work was done by a team consisting of Cedar Rapids BPL Steering Committee members. The Test Team consisted of:

- **Mr. James Spencer, WØSR, Test Site Host**
- **Mr. Roderick Blocksome, KØDAS**
- **Mr. Alan Erickson, WBØOAV**
- **Mr. Dale Svetanoff, WA9ENA, Test Leader**

[11] Although this test did not obtain data from multiple geographic locations to directly support this statement, it is a well-known characteristic of long wire antennas. Ref: *Radio Handbook*, 22nd Edition, William I. Orr, Howard W. Sams & Co., 1981, pp. 28.2 to 28.3.

8. ABOUT THE CEDAR RAPIDS BPL STEERING COMMITTEE

BPL Steering Committee Personnel and Mission Statement

Who We Are:

A group of concerned members of the Cedar Rapids area community who are active in the support of public service and emergency communications in the community through the use of Amateur Radio and who are experts in commercial and military communications technologies through their employment.

The members of the Cedar Rapids BPL Steering Committee are:

Mr. Ronald Breitwisch, KCØOX, Chairman

Ron Breitwisch has 29 years experience as a design and systems engineer at a major communications and avionics company. His background includes RF and digital design, including HF and VHF receivers and power amplifiers. He is currently the Chief Engineer for an Inmarsat L-band satellite communications system. He holds a BS degree in Electrical Engineering (Univ. of Wisconsin 1975). He is a licensed Advanced Class Amateur Radio operator, and holds a certificate of the formerly issued FCC First Class Radiotelephone license. He is currently the Amateur Radio Emergency Service ("ARES") District Emergency Coordinator for a 7 county area in Iowa, and is an active volunteer with Linn County (Iowa) Emergency Management Agency.

Mr. Roderick Blocksome, KØDAS

Rod Blocksome holds Amateur Radio Extra Class License, KØDAS, and has been continuously licensed and active in Amateur Radio for the past 44 years. He operates all amateur bands from 1.8 MHz thru 2304 MHz, and is active with ARES. He holds a certificate of the formerly issued FCC First Class Radiotelephone license. He holds BSEE, 1968, and MSEE, 1974, degrees. His professional experience includes 4 years in US Air Force as a Communications Engineering Officer and 37 years as an HF equipment designer, engineering manager, and communications systems engineer with a major aerospace company. He has authored numerous technical papers and magazine articles dealing with HF through microwave topics, and holds one U.S. patent.

Mr. Alan Erickson, WBØOAV

Alan Erickson works for a major aerospace company in military communications, where he has been employed in RF power amplifier design and systems engineering for 30 years. His project experience extends from HF through UHF and L-band frequencies, transmitter power levels up to 50 kW, and includes both narrow and broadband modulation types including OFDM. He holds a BA, and a BSEE in Electrical Engineering (University of Illinois, 1974) and holds four patents directly related to RF design. Alan is a licensed Extra Class amateur radio operator with call sign WBØOAV, and was first licensed in 1969. He holds a certificate of the formerly issued FCC First Class Radiotelephone license, and is active with ARES.

Mr. Alvin Groff, KØVM

Alvin Groff is retired after 37 years working for a major communications and avionics company. He held technical and engineering positions in micro-electronics design. He holds an Associate in Electronics Technology degree (Iowa State University, 1963). He is an Extra Class amateur radio operator, call KØVM, first licensed in 1959, and active ever since, including ARES. He holds a certificate of the formerly issued FCC First Class Radiotelephone License.

Mr. H. Thomas Hauer, KØYA

H. Thomas (Tom) Hauer is Director, Strategic Business Development for a major communications company in Cedar Rapids, Iowa. Prior to that, Tom was a Program Manager for both SATCOM and HF programs. Tom has over 30 years experience in communications from HF to Ka Band. He has participated in design, testing and manufacturing of numerous satellites including the first high power broadcast satellites, DSCS III, GPS, Spacenet, G-Star, Americom and numerous others. Tom holds a BSEE from Drexel University and MBA from Nova Southeastern University.

Tom has been an active Amateur Radio operator for over 43 years and holds an Extra Class license, call sign KØYA. He is an active participant in ARES and is vice president of the Eastern Iowa DX Association.

Mr. James Spencer, WØSR

James Spencer is a retired engineering executive with 39 years experience at a major electronics firm. He was involved in the design and management of communications and aviation electronics systems for both commercial and military customers. He holds a BSEE/MSEE from the University of Wyoming and is an Extra Class Amateur licensee with the call sign WØSR, first licensed in 1953. He also holds a certificate of the formerly issued FCC First Class Radiotelephone license. He is a licensed Professional Engineer in the state of Iowa and is active with the ARES.

Mr. Dale Svetanoff, WA9ENA

Dale Svetanoff has worked in telecommunications, medical and industrial imaging, RF shielding, and aerospace communications and avionics systems for more than 35 years. He has been issued 3 patents, is a member of the IEEE and IEEE Standards Association, chair of an IEEE standards working group, and has participated in the updating of military standards which pertain to electromagnetic effects. He served in the US Air Force Reserves (ground radio systems) and is presently employed as a Senior Electromagnetic Compatibility Engineer ("EMC"). Dale has been a Certified N.A.R.T.E. EMC Engineer for more than 12 years. He has been an active Amateur Radio operator since 1962, presently holding the Advanced Class call WA9ENA, and operates on most HF, VHF, and UHF bands. He is a registered Emergency Responder for communications assistance in Jones County, Iowa, and is active with ARES.

Dr. Robert W. Walstrom, WØEJ

Robert W. Walstrom has 30 years of active engineering experience in the U. S. Air Force and with a major communications design and manufacturing company. His broad practical experience spans HF, VHF, and UHF radio, global positioning systems, and satellite communications development and design. He has earned BS (South Dakota State University, 1970), MS and PhD (Iowa State University, 1971, 1979) degrees all in electrical engineering and is a registered Professional Engineer (Iowa and California). He has held a certificate of the formerly issued FCC First Class Radiotelephone license and has been a licensed Amateur Radio operator (Amateur Extra Class) for over 40 years. Dr. Walstrom represents Iowa, Missouri, Kansas, and Nebraska as a Director on the American Radio Relay League ("ARRL") Board of Directors. He is active in ARES.

What We Are Doing:

HF radio has been the basis for communications since the beginning of wireless RF communications. It has been used by government and military personnel, civil defense and emergency services personnel, commercial businesses, shortwave broadcasters, Amateur Radio operators and shortwave listeners for nearly 100 years in times of peace, war, and natural disaster.

This committee is committed to preserving the ability of these services to use the MF and HF radio spectrum in the Cedar Rapids community and throughout the United States.

How We Are Going To Do It:

The committee will support active Amateur Radio HF operators, businesses, and other commercial and government users of HF communications in the Cedar Rapids community to identify harmful interference caused by BPL, make valid interference measurements, contact the party responsible for causing the harmful interference, file required complaints and reports with the interfering party as well as the FCC, and provide necessary technical support to validate their claims.

The committee will work with the local power utilities demonstrating or implementing BPL and the businesses whose technology is being demonstrated or implemented to help them identify harmful interference, locate the specific causes of the harmful interference, and ensure that the harmful interference is eliminated.

The committee will work with the ARRL, The National Association For Amateur Radio, and enlist their assistance to ensure that all efforts by the committee are valid, properly documented, and completed with the utmost attention to honesty and integrity.

The committee will file responses to requests by the ARRL and the FCC for comment on technical issues associated with the regulation of BPL and with identifying, understanding and eliminating harmful interference from BPL systems.

The committee will adhere to the highest moral and ethical standards in all its actions.

APPENDIX 1

PART A: Test Data Plots

These are composite plots made from data taken on April 8th ("BPL ON") and May 19th ("BPL OFF"), unless otherwise noted. The 1 μV reference line has been inserted at -107 dBm, which is the equivalent level in a 50 ohm impedance. A "Ham Band" reference line shows the frequency limits of applicable Amateur Radio bands within the plots. As Table A-2 demonstrates, a desired signal at this level is more than adequate for producing a usable signal-to-noise ratio in all receivers listed. Unwanted signals at or above this level will produce anything from significant noise to destructive interference that renders copy of the desired communication impossible.

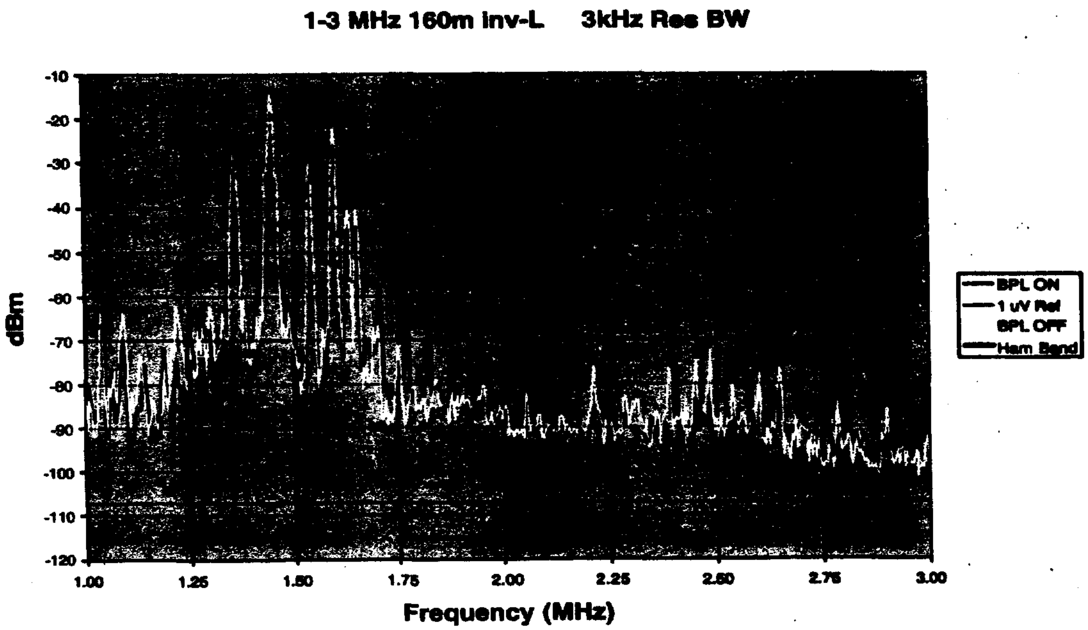


Fig. A1A-1: The spectrum from 1 to 3 MHz as "seen" by the 160m Inverted-L antenna. The Amateur Band of 1.8 to 2.0 MHz is at the center of the plot. The yellow trace shows strong AM broadcast band signals (left side) and various impulse noise s (right side).

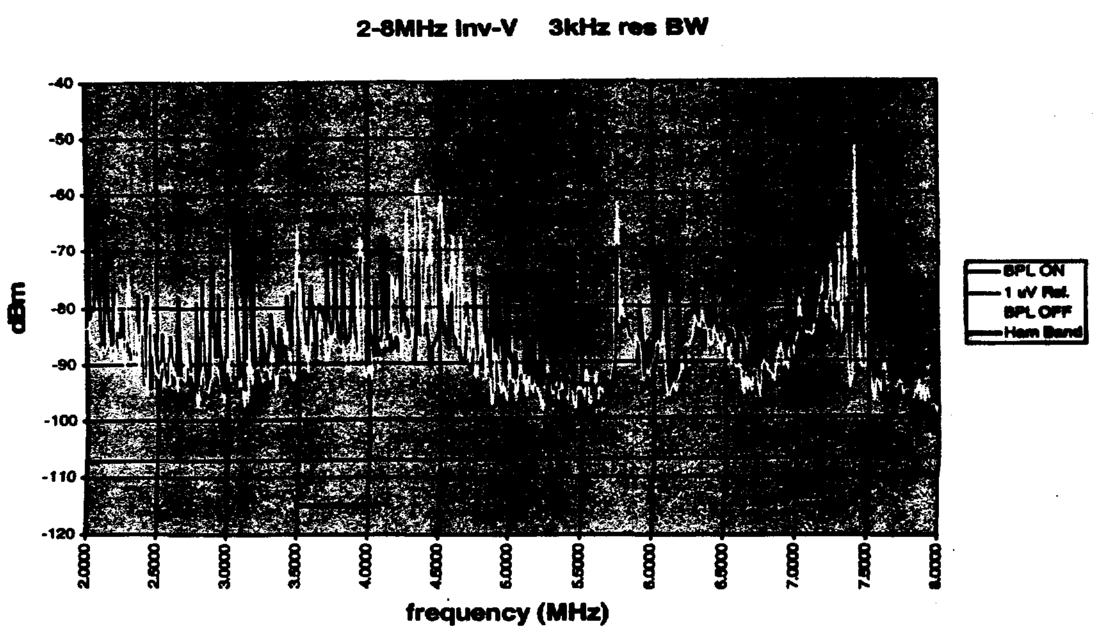


Fig. A1A-2: The spectrum from 2 to 8 MHz as "seen" by the dual band Inverted-V antenna. This view actually encompasses three (3) Amateur bands: 80m (just left of center), 60m (center), and 40m (right end). Note the BPL notching for 80m that isn't quite at the correct frequencies, and for 60m. There does not appear to be an effective notch for 40m at the

time this data was taken. The signal peaks on the yellow trace were audibly identified as typical of noise from power lines due to corona and arcing.

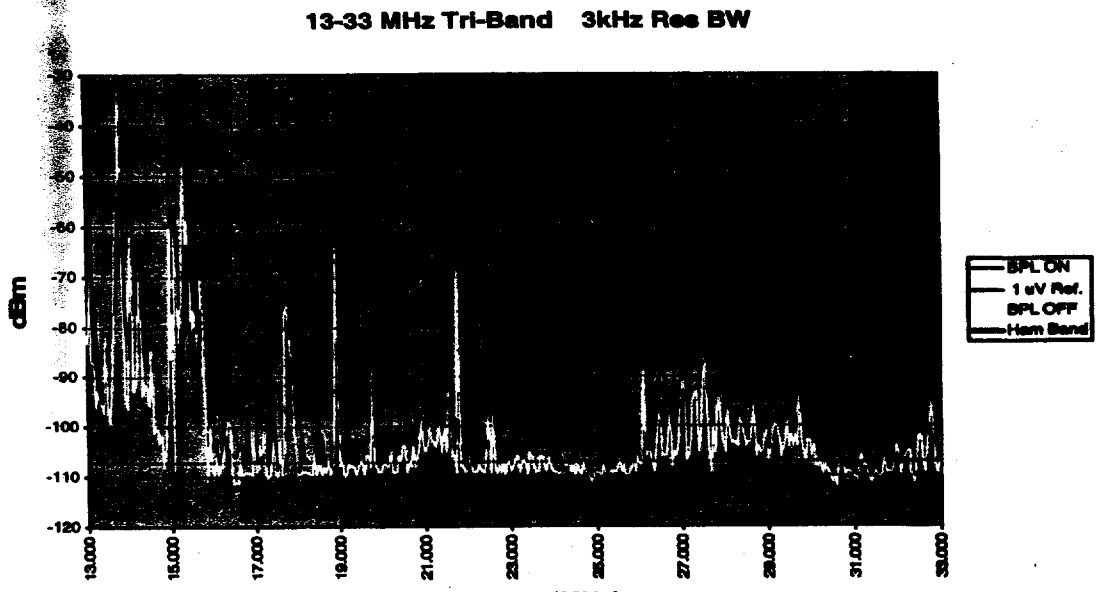


Fig. A1A-3: The spectrum from 13 to 33 MHz as seen by the Tri-Band beam. This range includes five (5) Amateur bands, although the antenna is designed for just three of them. The 20m band is to the left, the 17m band is one-third from left, the 15m band is just left of center, the 12m band is just right of center, and the 10m band is one-third from right. Note the high BPL and noise levels in and near the 20m and 10m bands. Some of the large signal peaks in yellow were audibly identified as short wave broadcast.

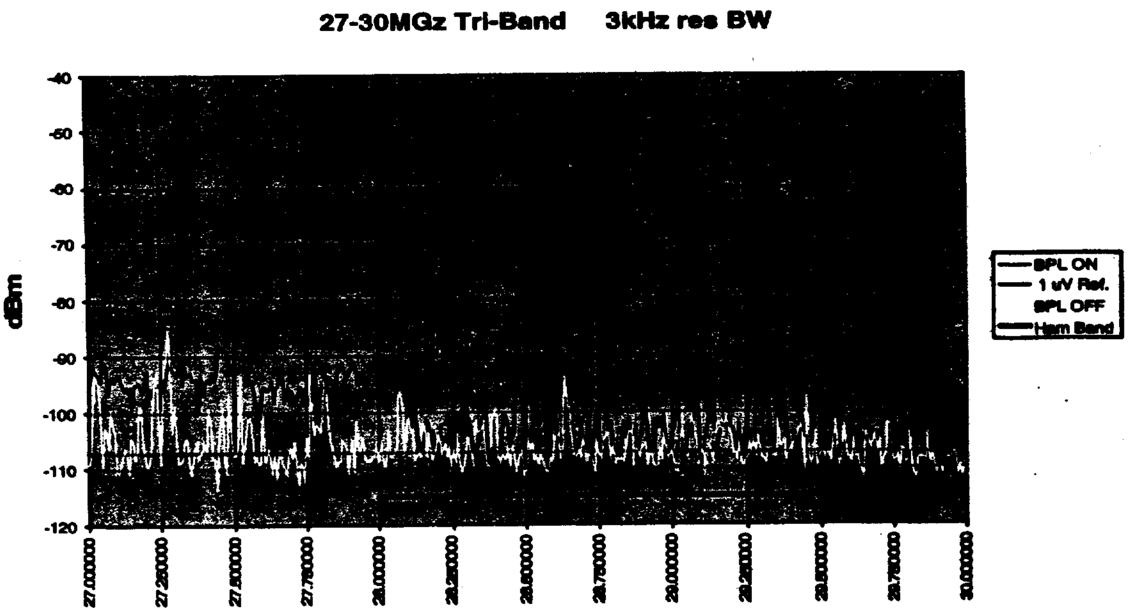


Fig. A1A-4: A close-in view of the 10m band as seen by the Tri-Band beam. The decrease in BPL signal (blue trace) is probably notching. Note that even the reduced level is several dB above the 1 μV reference line, meaning that these would still be loud signals into the receiver.

The three graphs which comprise Figure A1A-5 are a detailed scan with the relatively narrow spectrum analyzer IF filter of 1 kHz. Keeping the video filter wider (at 3 kHz) meant that the BPL signal "signature" was more readily visible. Because of the resolution obtained with this method, the plots shown are each the composite result of stringing three consecutive frequency range sweeps together. (Each sweep was only 50 kHz wide.) The data for these graphs was taken on the evening of May 19th after the BPL system re-started, following the 2 hour shut-down.

21.00 to 21.15 MHz   1kHz res BW

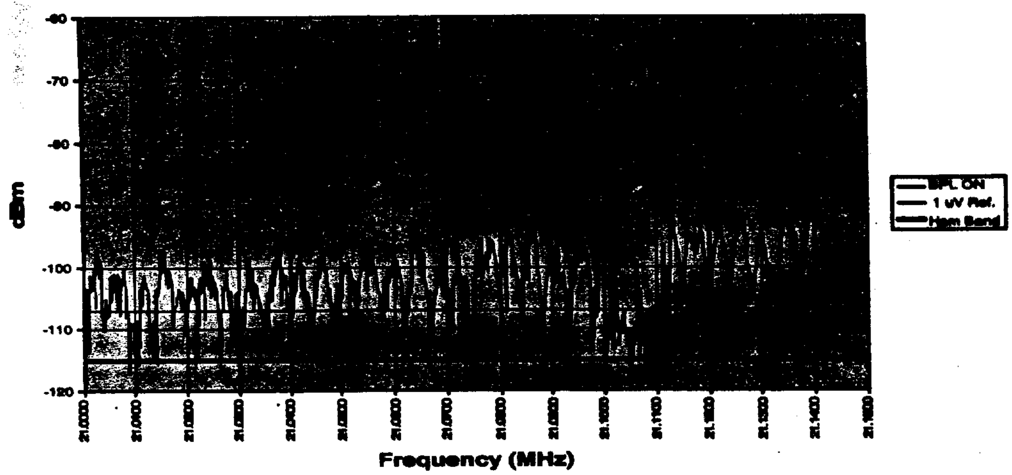


Fig. A1A-5a

21.15 to 21.30 MHz   1kHz res BW

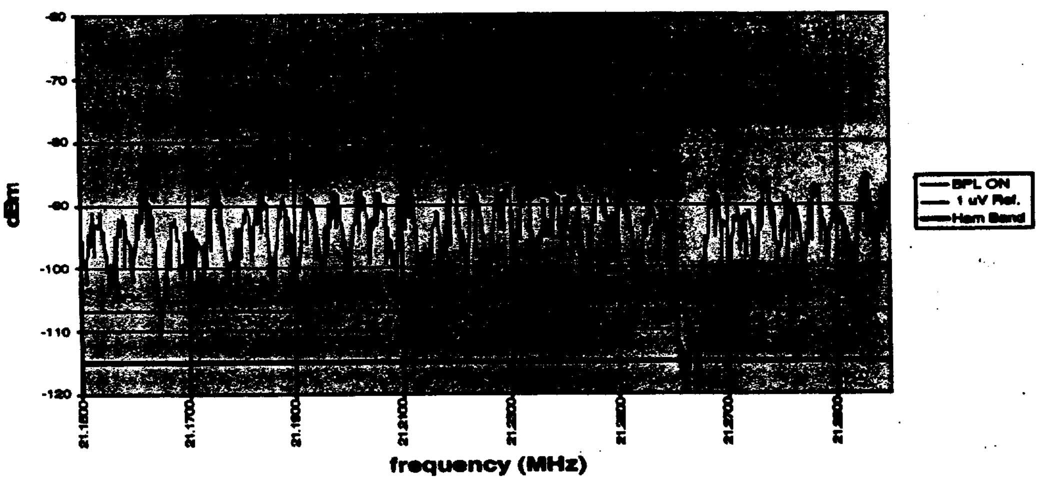


Fig. A1A-5b

21.30 to 21.40 MHz   1kHz res BW

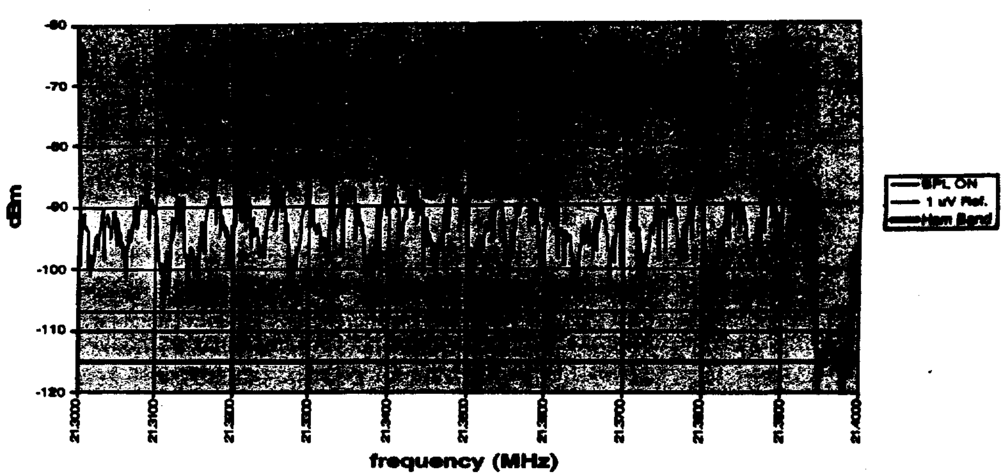


Fig. A1A-5c

The graphs of Figure A1A-5 clearly show that the BPL signals range from 10 to 15 dB, on average, over a 1 microvolt signal. These are loud and very audible in any voice-capability receiver tuned in this range. (Due to the characteristics of 21 MHz propagation, sky wave signals were essentially non-existent in the evening hours.)

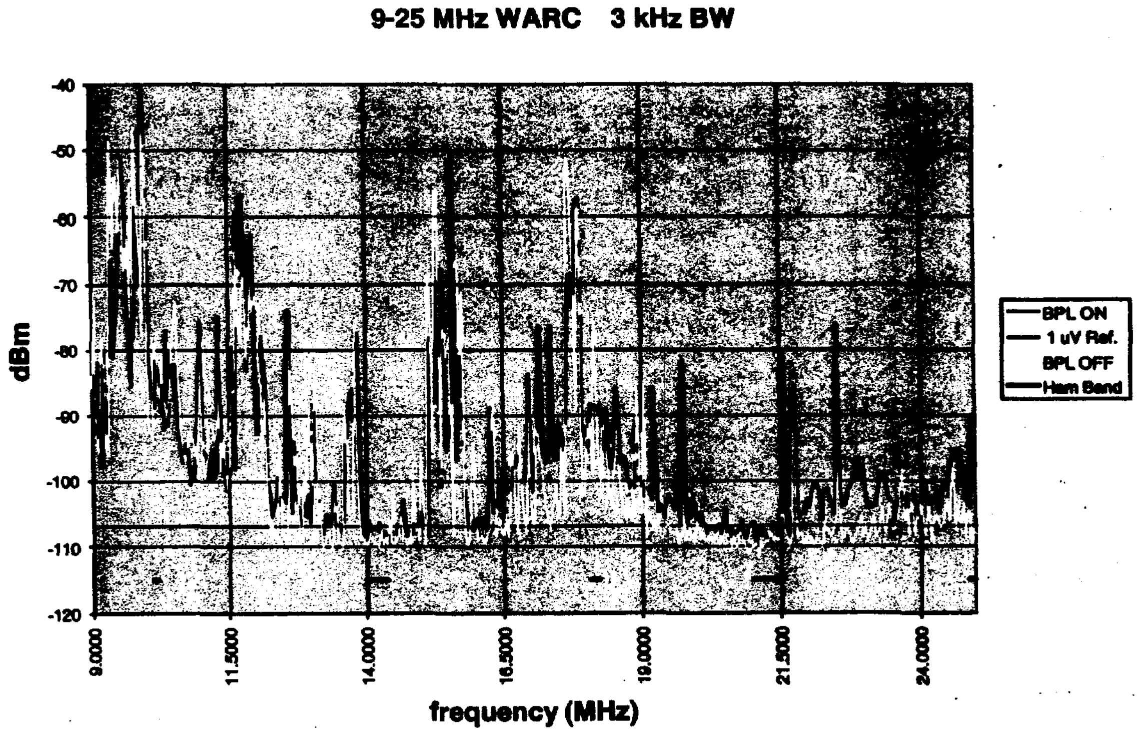


Fig. A1A-6: The spectrum from 9 to 25 MHz as seen by the WARC dipole. All three WARC bands are visible in this sweep, with 30m being to the left, 17m just right of center, and 12m at the far right edge.

These plots were taken late afternoon on two different days; at this point in the solar cycle, sky wave propagation above 20 MHz was nearly non-existent. However, strong signals which appear in the ranges below 20 MHz are a mix of sky wave (communication) signals, noise bursts and transients, and some BPL (blue trace).

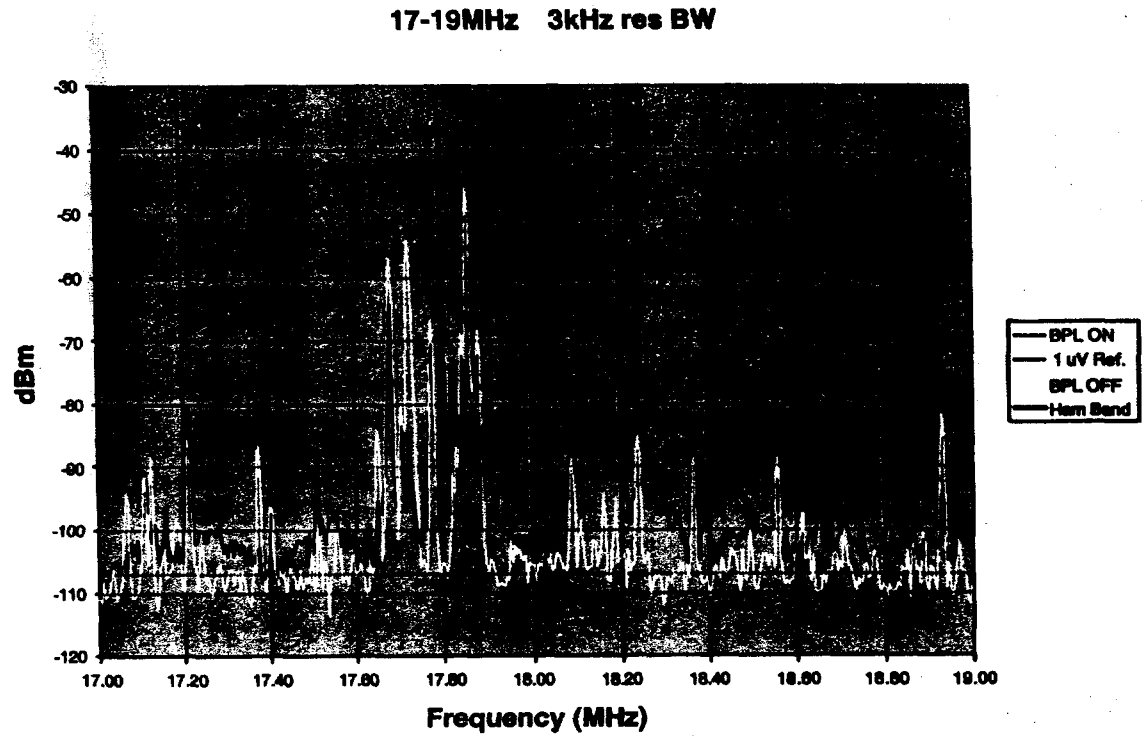
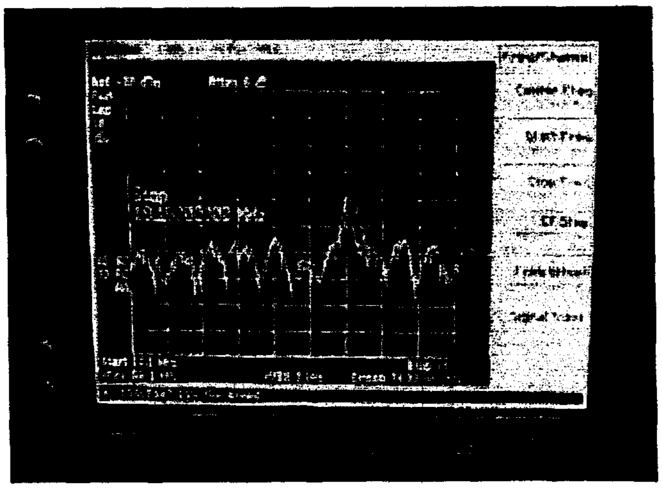


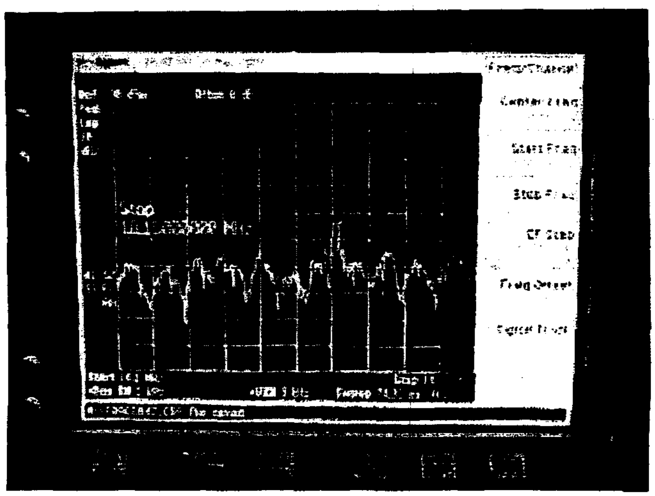
Fig. A1A-7: Spectrum detail between 17 and 19 MHz using the WARC dipole. The Amateur 17m band (which is 18.068 to 18.168 MHz) is just right of center. It appears that the BPL signals (blue trace) may have been notched; if so, the notch was not correct, being too low in frequency.

PART B: Spectrum Analyzer Sweep Photographs

The changing nature of BPL signals makes it very difficult to capture the transition that occurs during the periodic operation of the BPL system. This is especially true for spectrum analyzer sweeps that are being stored as data. The nature of the instrument is such that it "freezes" the signal captured by its circuits at the nearest instant in time that the sweep in progress completes when the "File Save" function is invoked. While it is possible to visually compare stored traces, or even overlay them for comparative analysis on a single graph, the most compelling image is that seen when the signal changes on a real-time dynamic basis. Some of these events were captured with fortuitous digital photographs that were taken as a transition occurred during spectrum analyzer multiple sweeps of one camera frame exposure. Here are some examples of those captured transitions:

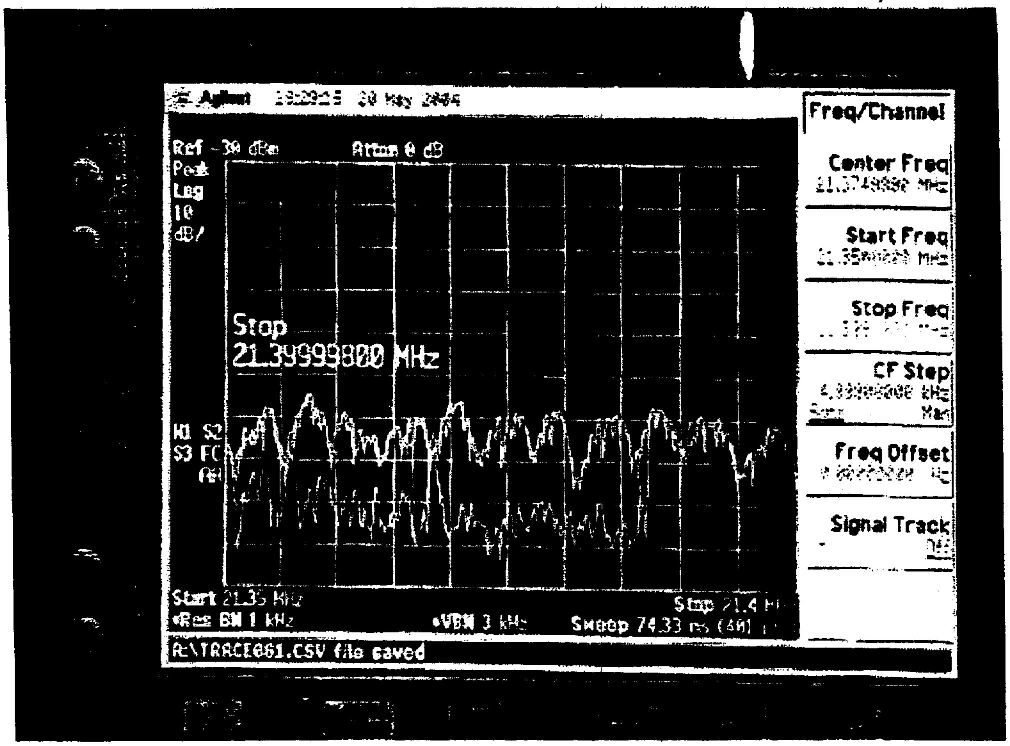
Note: These photographs are presented as supplemental to the data plots of Part A of this Appendix. For discussion purposes, the top of the spectrum analyzer graph is at the Reference Level of -30dBm. Each division on the vertical axis is 10 dB. An approximation of the signal level at any given frequency within the sweep range can be seen in the photographs. Detailed plots with full data were taken, but the transitions were not captured on any single graph. The resolution bandwidth used for all of these sweeps was 1 kHz so as to improve imaging of the BPL signal carriers.

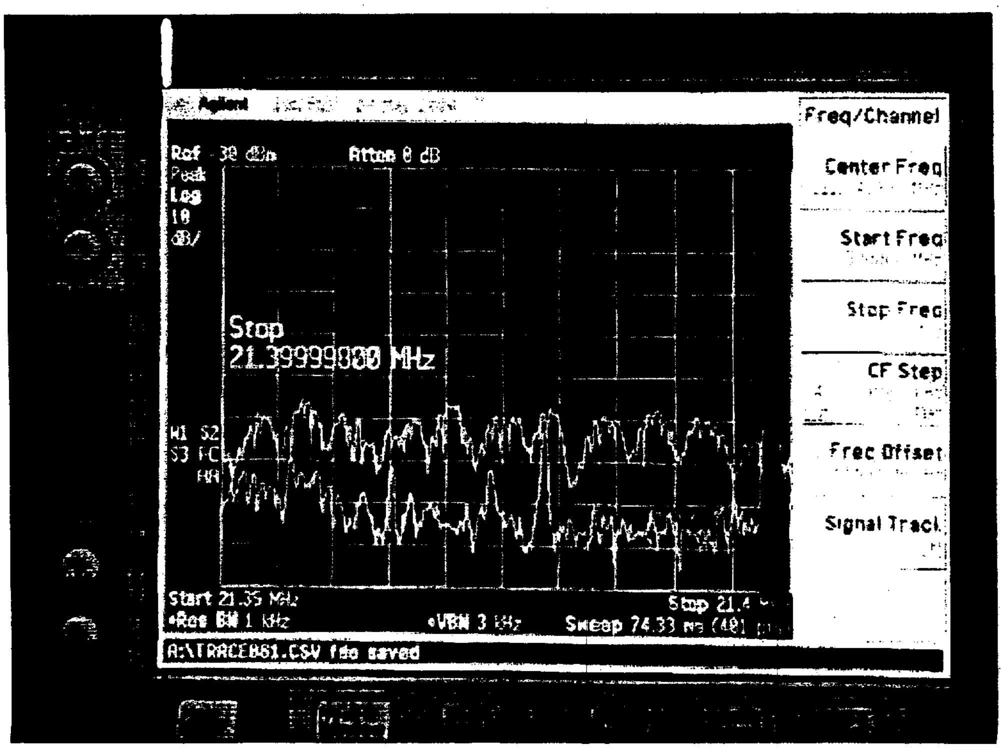




Figures A1B-1 (upper) and A1B-2 (lower)

These figures show two sets of sweeps from 18.1 MHz to 18.15 MHz in which the highest level BPL signal (slightly right of center) was transitioning due to its OFDM modulation.





Figures A1B-3 (upper) and A1B-4 (lower)

These figures each show two successive sweeps from 21.35 MHz to 21.4 MHz in which the BPL signals were transitioning between levels. The average level change across the frequency span was about 20 dB, although some carriers went to a peak as most of the others lowered. Figure A1B-3 actually caught the transition in progress (right end of trace).

APPENDIX 2
COMMUNICATION RECEIVER CHARACTERISTICS

The term "communication receiver" has been used several times in this report. It has also been stated that the spectrum analyzer's characteristics have been carefully matched to those of communication receivers so that the net data taking environment would closely replicate that of the typical Amateur Radio HF station. The noise floor (which defines the lowest level of signal that can be visually detected on the sweep trace) of the E4411B spectrum analyzers, when using an IF filter bandwidth of 3 kHz and video filter of equal or greater bandwidth, is about -110 dBm, or approximately 0.7 microvolts ("μV"). This places the spectrum analyzer within an order of magnitude for sensitivity (at comparable bandwidth) of most communication receivers (see Table A2-1). At 1 kHz IF filter bandwidth, and 300 Hz video filter bandwidth, the noise floor is at -115 dBm, or approximately 0.4 μV. These bandwidth settings were used to visualize the individual BPL carriers.

Due to the variabilities of HF sky wave and ground wave propagation, HF receivers must have high sensitivity[12] and effective automatic gain control ("AGC") to combat fading. Yet, as the ARRL test lab notes in their extended product test reports[13], "Most modern receivers have a noise floor within a few dB of 'perfect'. A perfect receiver would hear only the noise of a resistor at room temperature. However, especially for HF receiving systems, the system noise floor is rarely determined by the receiver. In most cases, external noise is many dB higher than the receiver's internal noise. In this case, it is the external factors that determine system noise performance. Making the receiver more sensitive will only allow it to hear more noise." Thus, designers of communication receivers have to work a fine design line between adequate sensitivity and sensitivity that is too great and which detracts from, rather than contributes to, useful communications.

Table A2-1 presents typical sensitivity (and related IF bandwidths, when the information is available) for a number of typical communication receivers, both past and current. Rohde *et al* state that for AM reception, a good receiver should have a nominal sensitivity of about 1.5 μV with a 6 kHz bandwidth for a 10 dB signal to noise ratio ("S/N"); a good SSB receiver should have about 0.1 to 0.3 μV sensitivity for 10 dB S/N, and a receiver for Morse, or CW, signals, should have a sensitivity of about 0.03 to 0.1 μV with a filter bandwidth on the order of 150 to 500 Hz[14]. Note that all of the sensitivity requirements noted are for achieving a specified signal-to-noise ratio, not a specific noise floor value.

The conclusion from examining the characteristics of the receivers in Table A2-1 and the performance of the E4411B is that a modern spectrum analyzer is capable of closely replicating the performance of communication receivers. The information presented above, and the data in Table A2-1, also show that receivers used by Radio Amateurs are on par with the state of the art and well suited to their intended purpose. One potentially negative aspect of many HF receivers (or receiving portion of transceivers) is that a pre-amplifier is included to boost weak signal sensitivity. This may be a useful feature under certain conditions, but the user of such a radio soon becomes aware that extra sensitivity results in just what the ARRL states – all that is heard is more noise. Fortunately, the pre-amplifiers are usually selectable for "in" and "out", and many receivers also include internal attenuators. These tend to decrease effective sensitivity, but under some circumstances, can actually improve the S/N of the desired signal. Skilled HF communicators know how to make use of their equipment's characteristics.

---

[12] *Communication Receivers: Principles and Design*, Ulrich L. Rohde, Jerry C. Whitaker, T.T.N. Bucher, McGraw-Hill, Second Edition, 1997, pg. 11.

[13] ARRL Laboratory Expanded Test-Result Report (any of many such reports), introductory remarks to the receiver noise floor tests. These expanded reports are available to ARRL members via the ARRL web site.

[14] *Communication Receivers: Principles and Design*, Ulrich L. Rohde, Jerry C. Whitaker, T.T.N. Bucher, McGraw-Hill, Second Edition, 1997, pp. 58-59.

Table A2-1: Receiver Characteristics

Make/Model	Description	Receive Frequency Tuning Range[15]	Rated/Measured Sensitivity @ Bandwidth[15,16] or Mode	Rated/Measured S-Meter Response[15]
Alinco DX-70TH	Current model basic transceiver	150 kHz to 30 MHz; 50 to 54 MHz	1.8 to 30 MHz: 0.25 μV 50 to 54 MHz: 0.15 μV all @ 2.4 kHz bandwidth	50 μV @ 14 MHz = S-9, pre-amp on; 146 μV @ 14 MHz = S-9, pre-amp off
Collins 75S-1	Late 1950's tube receiver	3.4 to 30 MHz	3.4 to 30 MHz: 1.0 μV for 15 dB S+N/N @ 2.1 kHz	~ 100 μV = S-9
Collins 75S-3	Early 1960's tube receiver	3.4 to 30 MHz	3.4 to 30 MHz: 0.5 μV for 10 dB S+N/N @ 2.1 kHz	~ 60 μV = S-9
Collins KWM-380	Late 1970's solid state transceiver	1.6 to 29.999 MHz	1.6 to 29.999 MHz: <0.5 μV for 10 dB S+N/N	Varies by band, range of 14 to 28 μV for S-9
Icom IC-706 MkII G	Current model wide range transceiver	30 kHz to 200 MHz; 400 to 470 MHz	1.8 to 30 MHz: <0.15 μV; 50 to 54 MHz: <0.12 μV – CW/SSB modes in both ranges	11 μV @ 14.2 MHz = S-9, pre-amp on; 34 μV @ 14.2 MHz = S-9, pre-amp off
Icom IC-718	Current model basic level transceiver	30 kHz to 30 MHz	0.03 to 30 MHz: <0.16 μV for 10 dB S/N, CW/SSB modes	38 μV @ 14 MHz = S-9, pre-amp on; 149 μV @ 14 MHz = S-9, pre-amp off
Icom IC-765	Early 1990's deluxe model transceiver	Amateur bands 1.8 to 30 MHz	1.8 to 30 MHz: 0.15 μV with pre-amp on	24 μV @ 14 MHz = S-9, pre-amp on; 65 μV @ 14 MHz = S-9, pre-amp off
Japan Radio Company JRC-135HP	1990's model transceiver	100 kHz to 30 MHz	1.6 to 30 MHz: 0.31 μV	37 μV @ 14 MHz = S-9
Kenwood TS-570S(G)	Current model transceiver	500 kHz to 30 MHz; 30 to 60 MHz	1.7 to 24.5 MHz: 0.2 μV; 24.5 to 30 MHz: 0.13 μV; 50 to 54 MHz: 0.13 μV, all for 10 dB S+N/N, CW/SSB/FSK modes	25 μV @ 14 MHz = S-9, pre-amp on; 94 μV @ 14 MHz = S-9, pre-amp off; 12 μV @ 52 MHz = S-9, pre-amp on; 90 μV @ 52 MHz = S-9, pre-amp off.
Kenwood TS-2000	Current model wide range transceiver	30 kHz to 60 MHz; 118 to 174 MHz; 220 to 512 MHz	1.7 to 24.5 MHz: <0.2 μV; 24.5 to 30 MHz: <0.13 μV; 50 to 54 MHz: <0.13 μV, all for 10 dB S/N, CW/SSB modes	24 μV @ 14.2 MHz = S-9, pre-amp on; 110 μV @ 14.2 MHz = S-9, pre-amp off; 15 μV @ 52 MHz = S-9, pre-amp on; 170 μV @ 52 MHz = S-9, pre-amp off.
Lowe HF-150	Early 1990's basic receiver	30 kHz to 30 MHz	0.5 to 30 MHz: 0.5 μV, pre-amp off; 0.2 μV pre-amp on, all for 10 dB S+N/N @ 2.6 kHz SSB bandwidth	N/A (receiver does not have an S-meter)

[15] Information taken from manufacturer's specification sheets or from ARRL test lab reports. In some cases, S-meter performance will vary by band or frequency range.
[16] Rated bandwidth information is from ARRL test lab reports, when available. In some cases, no information is available to indicate the bandwidth used for determining performance specifications.